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PAGE

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Part III—THE EFFECT OF PHOSPHORUS AND LIME ON THE MINERAL COMPOSITION OF THE SOIL AND GRASS

by J. A. Bonnet and A. R. Rivera 57

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Part IV—EFFECT OF UREA ADDED TO GRASS FERTILIZED WITH LIME AND PHOSPHORUS ON THE NUTRITION AND HEALTH OF GOATS

by J. A. Bonnet, A. R. Rivera, L. Rivera Brenes and R. Orlandi 67

ATTEMPT TO RECLAIM WITH CHEMICALS A SALTY CLAY IN PUERTO RICO

By J. A. Bonnet, P. Tirado Sulsona and M. A. Lugo López 75

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Vol. XXXIII APRIL 1949 No. 2

TABLE OF CONTENTS

PAGE

TRACING THE MINERAL FROM THE SOIL TO THE PLANT TO THE ANIMAL BLOOD

Part III—THE EFFECT OF PHOSPHORUS AND LIME ON THE MINERAL COMPOSITION OF THE SOIL AND GRASS

by J. A. Bonnet and A. R. Riera 57

TRACING THE MINERAL FROM THE SOIL TO THE PLANT TO THE ANIMAL BLOOD

Part IV—EFFECT OF UREA ADDED TO GRASS FERTILIZED WITH LIME AND PHOSPHORUS ON THE NUTRITION AND HEALTH OF GOATS

by J. A. Bonnet, A. R. Riera, L. Rivera Brenes and R. Orlandi 67

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TRACING THE MINERAL FROM THE SOIL TO THE PLANT TO THE ANIMAL BLOOD

Part III—The Effect of Phosphorus and Lime on the Mineral Composition of the Soil and Grass

J. A. BONNET and A. R. RIERA *

INTRODUCTION

A field experiment was started on June 25, 1943 in soil type Fajardo clay, at the Agricultural Experiment Station, Río Piedras, to study the effect of the application of lime on the mineral composition of the soil and of the grass. To raise this acid soil to about pH 6.5, the limed plots received applications from eight to ten tons of limestone per acre. The field was planted to a mixture of Para grass *Panicum purpurascens* and Carib grass *Eriochloa polystachya* and seven consecutive crops were harvested in a period of three years and two months up to August 23, 1946. The yields and the mineral analyses for the second, third, and fourth grass crops, and for the soil samples, taken 15 and 23 months after liming, were reported by Bonnet (1) and then by Bonnet and Riera (2). In the latter paper, the methods used and the protein contents for the five crops, as well as the yield of the fifth crop, are also given. The mineral analyses comprise calcium, magnesium, manganese, phosphorus and iron. The results obtained (1) were as follows: "The increase of available calcium and phosphorus and the decrease of available iron in the soil due to liming was highly significant 15 and 23 months after the lime was applied to the soil. The decrease of available manganese in the soil due to liming was highly significant 15 months after liming and significant 23 months after liming. The difference between the available magnesium content of the limed and unlimed soil was not significant.

"The increase of calcium and the decrease of manganese in the grass due to liming was highly significant for the second and third crops; the increase of calcium was significant for the fourth crop, and the decrease of manganese was not significant. The increase of phosphorus in the grass due to liming

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was highly significant for the second and fourth crops but was not significant for the third crop. There was no significant change in the iron content of the grass due to liming in the three crops and in the magnesium content of the second and fourth crops. The increase of magnesium in the grass crop due to liming was highly significant for the third crop.

"The increase in the grass yield due to liming was significant for the first and third crops. The difference between the respective yields of the unlimed and limed soil for the second, fourth and fifth crop, and for the total of five crops, was not significant."

EXPERIMENTAL WORK

The same field used previously by Bonnet and Riera (1, 2), was selected for the experiment.

Each of the original 18 plots, half of which received lime, were subdivided. The field consisted then of 36 plots, each with an area of two-tenths of an acre. The four treatments were: check, unlimed, phosphorus and lime-phosphorus. Superphosphate at the rate of 200 pounds P_2O_5 per acre was applied in the row, on November 7, 1945.

Soil samples were taken to a six-inch depth from each plot on February 18, 1946, 32 months after the lime or 3.4 months after the phosphorus applications. Samples were taken again on September 13, 1946, 39 months after the lime or 10.3 months after the phosphorus applications.

Two other crops were harvested; the sixth, in the middle of March 1946 when about eight months old; and the seventh, in the third week of August 1946 when about five months old. The latter crop received an application of ammonium sulphate at the rate of 500 pounds to the acre.

PRESENTATION AND DISCUSSION OF DATA

The pH and the amounts of available calcium, magnesium, manganese, phosphorus and iron, in the soil samples taken 32 and 39 months after liming or 3.4 and 10.3 months after the phosphorus application, are reported in table 1. The table contains also the mineral data reported previously (1, 2) for the soil samples taken 15 and 23 months after liming, but this time the figures are expressed in terms of pounds to the acre rather than in parts per million.

TABLE 1.—SOIL pH AND AVAILABLE CALCIUM, MAGNESIUM, MANGANESE, PHOSPHORUS AND IRON, IN FAJARDO CLAY (dry basis).

Time of Sampling	Treatment	pH	Pounds to the Acre				
			Ca	Mg	Mn	P	Fe
15 months after liming	Unlimed	4.6	1,698	360	84	26	34
	Limed*	6.3	13,662	344	16	122	4
23 months after liming	Unlimed	4.4	1,984	312	58	42	90
	Limed	6.3	10,702	312	10	112	24
32 months after liming or 3.4 months after phosphorus was applied	Unlimed	4.4	1,780	334	188	82	102
	Limed	6.3	11,412	442	42	156	16
	Phosphorus**	4.3	1,902	288	148	82	104
	Lime & Phosphorus	6.0	11,108	326	56	164	22
39 months after liming or 10.3 months after phosphorus was applied	Unlimed	4.6	1,580	346	80	52	74
	Limed	6.0	9,360	344	14	74	10
	Phosphorus	4.5	1,920	294	82	62	90
	Lime & Phosphorus	6.3	11,500	292	12	110	10

* Limestone, 8 to 10 tons to the acre.
** Superphosphate, 200 lbs. P_2O_5 to the acre.

The soil reaction varied from pH 6.0 to 6.3 in the limed soil, 32 and 39 months after the lime was applied. That of the unlimed soil varied from pH 4.3 to 4.6.

The effect of the lime on the mineral composition of the soil, 32 and 39 months after liming, was similar to that reported by Bonnet and Riera (1, 2) for the soil samples taken 15 and 23 months after liming. That is, there was a highly significant increase in the available calcium and a highly significant decrease of the available manganese and iron, of the soil, and no significant difference for the magnesium. There was also a highly significant increase in the soil available phosphorus, 32 months after the lime application, but this time, there was no significant increase of the soil available phosphorus during the 39 month period.

When phosphorus was applied, without lime, there was no significant difference in the soil available phosphorus. When phosphorus was applied with the lime there was a highly significant increase in the soil available phosphorus, 3.4 and 10.3 months after the phosphorus application. At the 3.4 month period, the lime treatment was as effective as the phosphorus-lime treatment, toward increasing the soil available phosphorus. But seven months later, the phosphorus-lime treatment was significantly better with regard to the increase of soil available phosphorus.

The addition of phosphorus, without the lime, had no significant effect in changing the available calcium, magnesium, manganese, phosphorus, and iron, of the soil.

The time of sampling and the mineral composition of the seventh grass crop are given in table 2 together with that for the second, third and fourth crops reported previously by Bonnet and Riera (1, 2).

TABLE 2.—TOTAL CALCIUM, MAGNESIUM, MANGANESE, PHOSPHORUS AND IRON IN FOUR CROPS OF PARA-CARIB GRASS GROWN IN SOIL TYPE FAJARDO CLAY (air dry basis).

Crop Numbe	Time of Sampling	Treatment	Parts per Million				
			Ca	Mg	Mn	P	Fe
Second	14 months after liming	Unlimed	2,199	1,509	229	2,100	149
		Limed	2,811	1,638	137	2,430	158
Third	17 months after liming	Unlimed	2,008	1,824	156	2,749	196
		Limed	3,351	2,212	84	3,047	160
Fourth	22 months after liming	Unlimed	2,919	2,166	243	2,450	124
		Limed	3,381	2,088	181	2,929	121
Seventh	28 months after liming or 9.6 months after phosphorus application	Unlimed	2,973	2,328	220	1,566	175
		Limed	3,839	2,171	125	1,991	111
		Phosphorus	3,229	2,216	247	1,829	126
		Lime & Phosphorus	3,762	2,170	129	2,082	130

The results obtained with the seventh grass crop due to the lime application were similar to those obtained with the second, third and fourth crops, as reported by Bonnet and Riera (1, 2). When lime or lime and phosphorus were applied, there was a highly significant increase of calcium and phosphorus and a highly significant decrease of manganese in the grass but the iron and magnesium contents were not affected. When phosphorus was applied without lime, there was a significant increase of phosphorus in the grass, but no significant change in the other minerals. There was also a significant difference between the phosphorus content of the grass that received phosphorus and that with calcium and phosphorus. The latter treatment had the higher content. There was no significant difference between the phosphorus content of the limed grass and the grass that received phosphorus or lime and phosphorus.

The fertilizer added to the soil, on November 7, 1945 contained 200 pounds of P_2O_5 to the acre equivalent to 87 pounds of P. This fertilizer was applied in the row of the corresponding plots, after the fifth grass crop was harvested. The first set of soil samples was taken 3.4 months after the fertilizer was applied and about one month previous to the harvest of the sixth grass crop. The second set of soil samples was taken 10.3 months after the fertilizer was applied or about three

weeks after the seventh grass crop was harvested. The available phosphorus present in the soil at the two sampling periods is reported in table 3.

TABLE 3.—AMOUNT OF AVAILABLE PHOSPHORUS PRESENT IN THE SOIL AT TWO SAMPLING PERIODS

Treatment	Available Phosphorus in the Soil after Superphosphate was Applied	
	3.4 months	10.3 months
	(P)	(P)
Unlimed	82	52
Limed	156	74
Phosphorus*	82	62
Lime and Phosphorus	164	110

* Received 87 lbs. P to the acre.

At the 3.4 month sampling period, the 87 pounds of available phosphorus (P) to the acre added in the fertilizer, were unaccounted for or fixed by the soil.

The yields and the mineral composition of the crops of Para-Carib grass for all the crops analyzed are reported in table 4. The minerals removed by each grass crop from the soil, in the unlimed, limed, phosphorus, and lime-phosphorus treaments, in pounds to the acre, are reported in table 5. The data were calculated from the mean values obtained in table 4.

TABLE 4.—YIELD OF CALCIUM, MAGNESIUM, MANGANESE, PHOSPHORUS, AND IRON IN FOUR CROPS OF PARA-CARIB GRASS GROWN IN FAJARDO CLAY
(dry basis)

Crop No.	Treatment	Yield Tons Acre	Ca Percent	Mg Percent	Mn Percent	P Percent	Fe Percent
2	Unlimed	2.24	.220	.151	.023	.210	.015
3	Unlimed	2.88	.201	.182	.016	.275	.020
4	Unlimed	2.68	.292	.217	.024	.245	.012
7	Unlimed	3.19	.297	.233	.022	.157	.018
MEAN		2.75	.252	.196	.021	.222	.016
2	Limed	2.41	.281	.164	.014	.242	.016
3	Limed	3.10	.335	.221	.008	.305	.016
4	Limed	2.59	.338	.209	.018	.293	.012
7	Limed	3.36	.384	.217	.013	.199	.011
MEAN		2.86	.335	.203	.013	.260	.013
7	Phosphorus	3.50	.323	.222	.025	.183	.013
7	Lime and Phosphorus	3.76	.376	.217	.013	.208	.013

The amount of calcium removed from the soil by each crop of Pará-Carib grass (table 5) varies from 14 pounds to the

TABLE 5.—POUNDS TO THE ACRE OF CALCIUM, MAGNESIUM, MANGANESE, PHOSPHORUS AND IRON REMOVED BY EACH CROP OF PARA-CARIB GRASS GROWN IN UNLIMED AND LIMED FAJARDO CLAY WITHOUT OR WITH PHOSPHORUS

Treatment	Ca	Mg	Mn	P	Fe
Unlimed	13.84	10.77	1.15	12.19	.88
Limed	19.19	11.63	.74	14.89	.74
Phosphorus	22.62	15.54	1.75	12.81	.91
Lime and Phosphorus	28.29	16.33	.98	15.65	.98

acre, in the unlimed treatment, to 28 in the lime-phosphorus treatment; the magnesium from 11 to 16; the phosphorus from 12 to 16 respectively, and the manganese and iron about one pound. The amount of available calcium in the soil, 39 months after the lime or 10.3 months after the phosphorus application (table 1) varies from 1580 pounds to the acre in the unlimed treatment, to 11,500 in the lime-phosphorus treatment; the magnesium from 346 to 292; the manganese from 80 to 12; the phosphorus from 52 to 110 and the iron from 74 to 10, respectively. This acid soil (pH 4.6) was well supplied with the above mentioned minerals for seven consecutive crops of Para-Carib grass without the addition of lime and phosphorus.

The yield and the age of each of the seven crops of Pará-Carib grass harvested are given in table 6. Bonnet and Riera

TABLE 6.—YIELD IN TONS TO THE ACRE OF SEVEN CONSECUTIVE CROPS OF GREEN PARA-CARIB GRASS HARVESTED IN FAJARDO CLAY

Treatment	Number and Age of Crops and Fertilizer Applied						
	1 5.75 mo. No Fertilizer	2 8.25 mo. No Fertilizer	3 3.50 mo. Nitrogen* Applied	4 4.25 mo. No Fertilizer	5 3.50 mo. Nitrogen* Applied	6 8.00 mo. No Fertilizer	7 5.00 mo. Nitrogen* Applied
Unlimed	8.98	7.47	9.59	8.92	9.82	1.95	10.64
Limed	11.0	8.03	10.33	8.62	9.81	1.53	11.20
Unlimed with Phosphorus**	.....	.....	.....	.....	.....	1.80	11.67
Limed with Phosphorus**	.....	.....	.....	.....	.....	1.57	12.54

* 500 lbs. ammonium sulphate to the acre.
** 200 lbs. P_2O_5 to the acre as superphosphate.

(1, 2) reported before: "The increase in the grass yield, due to liming, was significant for the first and third crop but was not significant for the second, fourth, and fifth crops, or for the total of the five consecutive crops." No significant difference was found between the grass yields of the four treatments given to the sixth or to the seventh crop. The addition of phos-

phorus, with or without lime, was not effective toward increasing the crop yield. The mean yield of all treatments of the seventh crop was 11.51 tons to the acre of green Para-Carib grass and that of the sixth crop was only 1.71 tons. The seventh crop yielded about seven times as much forage as the sixth crop. This increase in yield was due to the application of 500 pounds to the acre of ammonium sulphate.

SUMMARY

Results are given here of the effect of adding phosphorus to an acid soil, limed or unlimed, on the pH and mineral composition of the red soil Fajardo clay. Data are also given for similar effect on the yield and mineral composition of a mixture of Pará grass *Panicum purpurascens* and Carib grass *Eriochloa polystachya*. The minerals studied were calcium, magnesium, manganese, phosphorus, and iron.

The main results are as follows:

1. Lime was still effective in keeping the soil slightly acid (pH 6.0 and 6.3) 32 and 39 months after it was applied. That of the unlimed soil was strongly acid, from pH 4.3 to 4.6.
2. There was a highly significant increase in the available calcium and a highly significant decrease of the available manganese and iron of the soil and no significant difference for the magnesium, 32 and 39 months after the lime application, when phosphorus was not added.
3. There was a highly significant increase in the soil available phosphorus, 32 months after the lime application but no significant difference at 39 months. At the latter period the lime was not effective in raising the soil available phosphorus.
4. The lime was as effective, 32 months after its application, as the phosphorus, 3.4 months after its application, in raising the soil available phosphorus. But seven months later, the phosphorus-lime treatment was significantly better than the lime treatment.
5. When lime or lime with phosphorus, was applied, there was a highly significant increase of calcium and of phosphorus and a highly significant decrease of manganese in the grass, but the iron and magnesium contents were not changed.
6. When phosphorus was applied without lime, there was a significant increase of phosphorus in the grass, but no significant change in the other minerals.

There was also a significant difference in the phosphorus content of the grass which received calcium and phosphorus. The latter had the higher content. There was no significant difference between the phosphorus content of the limed grass and the grass which received phosphorus or lime and phosphorus.

7. At the sampling period, 3.4 months after the superphosphate application, the 87 pounds of available phosphorus (P) to the acre applied, were unaccounted for or fixed by the soil.
8. No significant difference was found between the yields of each of two consecutive crops of Para-Carib grass mixture due to the addition of phosphorus to an acid soil, with or without lime.

RESUMEN

Se informa aquí el efecto que ha tenido una aplicación de fósforo, en la ausencia o presencia de cal, sobre el pH y la composición mineral del suelo rojo y ácido, Fajardo arcilloso. También se informa el efecto que ha tenido dicha aplicación de fósforo sobre el rendimiento y la composición mineral de una mezcla de yerbas Malojillo *Panicum purpurascens* y Malojilla *Eriochloa polystachya*. Los minerales estudiados fueron calcio, magnesio, manganeso, fósforo y hierro.

Los resultados obtenidos se resumen como sigue:

1. La cal sostuvo la reacción del suelo, ligeramente ácida (pH 6.0 y 6.3), a los 32 y 39 meses después de su aplicación. El suelo ácido tuvo en dichos períodos, una reacción fuertemente ácida (pH 4.3 y 4.6).
2. A los 32 y 39 meses después de aplicar la cal sola, se produjo un aumento en el calcio asimilable del suelo y un descenso en el manganeso y en el hierro asimilable, lo cual fué altamente significativo en ambos casos. No hubo diferencia significativa en el magnesio.
3. A los 32 meses después que se aplicó la cal sola se produjo un aumento altamente significativo del fósforo asimilable en el suelo; pero a los 39 meses no hubo diferencia significativa. El efecto de la cal en aumentar el fósforo asimilable en el suelo fué nulo a los 39 meses.
4. La cal fué tan eficiente a los 32 meses después de su aplicación como lo fué el fósforo a los 3.4 meses después de aplicado, para subir el contenido de fósforo asimilable del suelo. Siete meses después, el tratamiento de cal y fósforo fué significativamente mejor que la cal sola.

5. La aplicación de cal al suelo, con o sin fósforo, produjo aumentos de calcio y fósforo en la yerba y descenso en el manganeso, lo cual fué altamente significativo en ambos casos. Los contenidos de hierro y magnesio no fueron afectados.
6. Cuando se aplicó el fósforo, sin la cal, hubo un aumento significativo de fósforo en la yerba pero no hubo cambio en los otros minerales. También hubo una diferencia significativa, entre el contenido de fósforo de la yerba en el tratamiento con fósforo y el tratamiento con cal y fósforo siendo mayor la diferencia en este último. No hubo diferencia significativa entre el fósforo de la yerba en el tratamiento con cal y en el tratamiento con cal y fósforo.
7. Las 87 libras de fósforo (P) asimilable del superfosfato no aparecieron en el suelo, a los 3.4 meses después de aplicada; lo que indica que el fósforo fué fijado en el suelo.
8. No hubo diferencia significativa, entre los rendimientos de dos cosechas consecutivas de yerbas Malojillo-Malojilla cuando se añadió fósforo a un suelo ácido, en la ausencia o presencia de cal.

LITERATURE CITED

1. **Bonnet, J. A.** Tracing the calcium, phosphorus, and iron from a limed and unlimed lateritic soil to the grass and to the animal blood. Soil Science Society of America Proc. (2):295–297. 1946.
2. **Bonnet, J. A. & Riera, A.** Tracing the mineral from the soil to the plant to the animal blood. Part I. Effect of lime on the mineral composition of the soil, of the grass, and on the crop yield. Jour. Agric. Univ. P. R. 30 (3):138–158, July 1946.

TRACING THE MINERAL FROM THE SOIL TO THE PLANT TO THE ANIMAL BLOOD

Part IV—Effect of Urea Added to Grass Fertilized with Lime and Phosphorus on the Nutrition and Health of Goats

J. A. BONNET, A. R. RIERA, L. RIVERA BRENES and R. ORLANDI *

INTRODUCTION

The authors have reported previously (3) the procedure followed and the data obtained in the first experiment on the effect of unlimed and limed Para-Carib grass on the health of the goat and the chemical composition of its blood. The main results obtained during the experimental period are summarized as follows:

"Goats fed with unlimed grass ate as much as those fed with limed grass. There was a highly significant decrease in the weight of the goats, a reduction in red and white blood cells; in hematocrits and in blood iron, but there was no change in the calcium and phosphorus of blood serum. Of a total of fifteen goats, ten aborted and one died, two delivered a weak kid each but produced no milk. At the end of this experiment all goats were emaciated."

Considering that the protein deficiency in the grass might have been the cause of the malnutrition of the goats and knowing that urea has been used successfully as a protein source for ruminants by different investigators (1, 4, 5, 6, 7, 8) it was considered advisable to study if urea added to the grass would prevent the malnutrition. This paper presents data on what effect the grass fertilized with phosphorus or lime and phosphorus and mixed with urea had on the health of the animal and on the chemical composition of its blood.

EXPERIMENTAL

The same field used in part III (2) was used. A mixture of Pará grass (*Panicum purpurascens*) and Carib grass (*Erio-*

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chloa polystachia) was cut daily from the corresponding strips of the unlimed, limed, phosphorus and lime-phosphorus treatments.

Sixteen one-year old virgin female goats were selected for the experiment. They were given a parasite treatment; 12 grams of phenothiazine per os. The animals were randomized into four groups, one in each pen, for the following treatments: 1. goats fed with unlimed grass, 2. goats fed with limed grass, 3. goats fed with phosphorus grass, 4. goats fed with lime-phosphorus grass.

Eight pounds of freshly chopped grass were fed to each animal. Five grams of c.p. urea (46.65% nitrogen) dissolved in 50 ml. of water were thoroughly mixed with the grass in an enamel pail before it was fed. This amount of urea was calculated to supply around 40 percent of the original amount of crude protein in the grass, known to be in previous analyses 3.5 percent on the average. As nothing was known about the response of goats to urea feeding that amount given was considered conservative.

A composite grass sample from each treatment was taken daily for moisture analysis. The amount of residual grass left daily was weighed and records of the green and dry matter consumed by each animal were kept.

Each goat was weighed three times in three consecutive days, at the middle and at the end of each month.

To induce uniform breeding, each goat was injected intramuscularly with 5 ml. of gonadin at the end of the pre-gestation period.

Blood samples were taken from each animal before and at the pre-feeding period, on January 21 and March 4, 1947 repectively; on April 8 and May 6, 1947 in the pre-gestation period; and finally on May 10 and August 25, 1947 during the gestation period. About 10 ml. of blood were drawn from each goat by a direct puncture of the jugular vein: 2 ml. for the hematological test and 8 ml. for the chemical test. Hemoglobin, iron, hematocrits, red and white blood cells were determined in the blood, and phosphorus in the blood serum, following methods previously described (3).

The experiment was started on February 17, 1947 and terminated on August 25, 1947. The six month period was divided as follows:

1. Pre-feeding (Feb. 17 to March 11, 1947)
2. Pre-gestation (March 12 to May 7, 1947)
3. Gestation (May 8 to August 25, 1947)

PRESENTATION OF DATA AND DISCUSSION

The mean weights per goat before and during the pre-gestation period and afterwards, are given in table 1. There was no significant difference between the grass treatments for the loss in weight of the goats during the three periods.

TABLE 1.—MEAN WEIGHTS PER GOAT FED WITH GRASS AND UREA AT PRE-FEEDING, PRE-GESTATION AND GESTATION PERIODS

Grass Treatment	Pre-feeding lbs.	Pre-gestation* lbs.	Gestation* lbs.
Check	61.3	53.6	53.1
Lime	53.3	48.5	43.4
Phosphorus	45.3	40.3	38.7
Lime-phosphorus	56.3	47.9	47.4

* At 2.5 and 5.5 months, respectively, after the pre-feeding period.

The protein content of the Pará-Carib grass mixture, including the urea, varied from 5.2 to 5.8 percent on the dry basis. The amount of protein was a little above the calculated but not much higher.

The amounts of dry Pará-Carib grass consumed by each goat, during the pre-gestation period of 57 days, and per day, are reported in table 2. There was no significant difference, between the treatments for the amount of grass consumed during the pre-gestation period. In the first experiment (3), it was found that "goats fed with unlimed grass ate significantly less than those fed with limed grass."

TABLE 2.—AMOUNT OF DRY PARA-CARIB GRASS CONSUMED BY EACH GOAT DURING PRE-GESTATION PERIOD

Grass Treatment	Dry Grass Eaten, lbs.	
	Per Period (57 days)	Per day
Check	66.2	1.16
Lime	74.3	1.30
Phosphorus	68.1	1.19
Lime-Phosphorus	71.4	1.25

The hematological data, iron in blood, and phosphorus in blood serum, for the goats, before and after the pre-gestation period and after the gestation period are reported in table 3.

TABLE 3.—HEMATOLOGICAL DATA, IRON IN BLOOD, AND PHOSPHORUS IN BLOOD SERUM, FOR GOATS

Grass Treatment	Period	Red Blood Cells Per Cu. mm.	White Blood Cells Per Cu. mm.	Hematocrits	Hemoglobin	Fe in blood	P in serum
		X 10^3		% vol.	gm. %*	mg. %*	mg. %*.
CHECK	Before pre-gestation....	21,365	13,225	42.7	12.9	62.7	4.0
	End of pre-gestation....	18,733	15,450	35.5	11.4	44.9	2.0
	End of gestation.....	17,108	11,600	31.5	11.1	32.1	3.5
LIME	Before pre-gestation....	19,073	11,400	39.1	11.7	60.1	3.7
	End of pre-gestation....	18,603	14,763	37.1	11.9	45.8	2.0
	End of gestation.....	14,640	11,650	28.8	10.2	28.1	3.0
PHOSPHORUS	Before preg-estation....	18,835	11,338	37.5	11.3	65.5	4.9
	End of pre-gestation....	20,828	19,750	38.9	12.2	46.8	1.6
	End of gestation.....	15,153	11,925	26.9	9.5	26.2	4.3
LIME— PHOSPHORUS	Before pre-gestation....	17,685	10,950	39.4	11.7	56.6	3.7
	End of pre-gestation....	19,448	14,400	35.3	11.4	44.8	1.5
	End of gestation.....	18,303	11,925	30.3	10.8	29.6	3.4

* Grams hemoglobin and milligrams Fe or P per 100 ml. blood or serum.

There was no significant difference between the grass treatments for the hemoglobin; the red and white blood corpuscles; the hematocrits; the blood iron and the blood serum phosphorus of the goats, during the pre-feeding, pre-gestation and gestation periods. The hematocrits of the blood during the gestation period, was significantly lower than that of the pre-feeding period. The iron content of the blood during the pre-gestation and gestation periods was lower (highly significant) than that of the pre-feeding period. There was a strong tendency for the phosphorus treatment to lower the hemoglobin content during the gestation period. The inorganic phosphorus content of the blood serum during the pre-gestation period was lower (highly significant) than that of the pre-feeding and the gestation periods.

Of the sixteen goats in this experiment, one died, one aborted and only four delivered kids. All the goats lost weight and at the end of the experiment, the animals showed malnutrition symptoms.

There are some reasons to consider as the cause of this malnutrition:

1. The goats did not eat enough roughage to meet their requirement of total digestible nutrients; they only ate about one half of the roughage given. This was due probably to the quality of the roughage, or the

state of maturity. Every day the grass was one day older until the plot was finished, introducing a large variation in quality.

2. Goats like to be in the open and do not behave well in confinement or under a controlled diet. Goats like to pick and eat here and there a large variety of plants.

Before starting this experiment the five grams of urea were fed in gelatine capsules to see if it was possible to use that method of feeding. Three of the goats had tetanic spasm and orthotonus effects and one died after feeding a second capsule. Post mortem lesions revealed hemorrhagic infarcts in the liver. This toxic effect was probably due to a rapid absorption of urea in the blood stream. Nothing happened when the five grams of urea dissolved in water were mixed with the grass fed. In spite of the noted malnutrition the amount of urea was not increased fearing harmful effects that would have been worse than the malnutrition itself.

SUMMARY AND CONCLUSIONS

The purpose of this paper was to find out what effect a low protein grass, with or without lime and phosphorus, supplemented with urea had on the health of the goat and on her blood chemical composition. Sixteen goats were separated into four groups and each group was fed with a corresponding mixture of Pará-Carib grass harvested in an acid soil that received four treatments: check, lime, phosphorus and lime-phosphorus. The goat experiment covered six months, including pre-feeding, pre-gestation, and gestation periods.

The results are summarized as follows:

1. The protein content of the grass, including the urea, varied between 5.2 and 5.8 percent on dry basis.
2. There was no significant differences, between the treatments, for the amount of grass eaten by the goats during the pre-gestation period.
3. There was no significant difference between the grass treatments, for the hemoglobin, the red and white blood corpuscles, the hematocrits, the blood iron, and the serum inorganic phosphorus of the goats, during the pre-feeding, pre-gestation and gestation periods. The hematocrits during the gestation period was significantly lower than that of the pre-feeding period of all the grass treatments. The iron content of the blood during the pre-gestation and

gestation periods was lower (highly significant) than that of the pre-feeding period. The inorganic phosphorus content of the serum, during the pre-gestation period was lower (highly significant) than that of the two other periods.

4. Of the 16 goats in this experiment, one died, one aborted and four delivered kids.
5. All the goats, at the end of the experiment, lost weight, were emaciated thus showing malnutrition symptoms.
6. The amount of urea eaten by the goats did not correct the malnutrition if it was due to low protein content.

RESUMEN

Este trabajo se hizo con el fin de determinar qué efecto tendría en la salud de la cabra y en la composición química de su sangre, una yerba baja en proteína, con o sin cal y fósforo, y una dosis extra de nitrógeno en la forma de urea. Diez y seis cabras fueron separadas en cuatro grupos y cada grupo consumió, respectivamente, el forraje de una mezcla de yerbas Malojillo-Malojilla, cosechada en un suelo ácido el cual recibió cuatro tratamientos, a saber: testigo, cal, fósforo y cal con fósforo. El experimento duró seis meses e incluyó tres períodos: alimentación inicial, pre-gestación y gestación. Los resultados se exponen así:

1. El contenido de proteína de la yerba, incluyendo la urea, varió de 5.2 a 5.8 por ciento.
2. En el período de la pre-gestación, no hubo diferencia significativa entre los tratamientos, en cuanto a la cantidad de yerba que consumió cada grupo.
3. Durante cada uno de los tres períodos del experimento, no hubo diferencia significativa entre los tratamientos, para los siguientes componentes de la sangre: la hemoglobina, los corpúsculos rojos y blancos, los hematócritos y el hierro; y el fósforo inorgánico del suero. En el período de gestación, los hematócritos fueron significativamente más bajos que en el período de alimentación inicial, para todos los tratamientos. El hierro en la sangre fué más bajo (altamente significativo) en los períodos de pre-gestación y gestación que en el período de alimentación inicial. El fósforo inorgánico del suero fué más bajo (altamente significativo) en el período de pre-gestación que en los otros dos.
4. De las 16 cabras usadas en el experimento, una murió, otra abortó y cuatro parieron cabritos.

5. Al finalizar el experimento todas las cabras perdieron peso y su apariencia física era muy pobre.
6. La cantidad de urea ingerida en la yerba no fué suficiente para corregir la malnutrición si ésta era debido al contenido bajo de proteínas.

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LITERATURE CITED

1. **Bartlett** and **Cotton, A. G.** Urea as a protein substitute in the diet of young cattle. Jour. Dairy Res. 9:263–272. 1938.
2. **Bonnet, J. A.** and **Riera, A. R.** Tracing the mineral from the soil to the plant to the animal blood. Part III.—The effect of phosphorus and lime on the mineral composition of the soil and of the grass and its yield. Jour. Agric. Univ. P. R. 33 (2): Apr. 1949.
3. **Bonnet, J. A.; Riera, A. R.; Rivera Brenes; L.** and **Orlandi, R.** Tracing the mineral from the soil to the plant to the animal blood. Part II—Effect of unlimed and limed grass on the chemical composition of goat's blood. Jour. Agr. Univ. P. R. 30 (3):159–183, July, 1946.
4. **Brigs H. M.; Gallup, W. P.; Darlow, A. E.; Stephens, D. F.** and **Kenney, C.** Urea as an extender of protein when fed to cattle. Jour. An. Sci. 6:445–459, 1947.
5. **Harris, L. E.** and **Mitchel H. H.** The value of urea in the synthesis of protein in the pouch of the ruminant. II in growth. Jour. Nutri- 22:183–196. 1941.
6. **Hart, E. B.; Bohstedt, G.; Deobald, H. J.** and **Wigner, M. I.** The utilzation of simple nitrogenous compounds such as urea and ammonium bicarbonate by growing calves. Jour. Dairy Sci. 22:785–798. 1939.
7. **Johnson, C. B.; Hamilton, T. S.; Mitchel, H. H.** and **Robinson, W. B.** The relative efficiency of urea as a protein substitute in the ration of ruminants. Jour. An. Sci. 1 (3):236–245. 1942.
8. **Work, S. H.; Hamre, C. J.; Henke, L. A.** and **Harris, L. E.** A note on the effect on the kidneys and livers of feeding urea to steers fattening in dry lot and on pasture. Jour. An. Sci. 2:166–169. 1943.

ATTEMPT TO RECLAIM WITH CHEMICALS A SALTY CLAY IN PUERTO RICO [1]

J. A. BONNET, P. TIRADO SULSONA and M. A. LUGO LÓPEZ [2]

INTRODUCTION

Lajas valley is located in the dry southwestern area of Puerto Rico where the mean annual rainfall is 31.35 inches. Recent records obtained in an open pan surface, from February to July 1949 inclusive, indicate that the monthly evaporation there varies between six and eight inches. An irrigation project for that area is now under construction by the Insular Government. Field and laboratory work reported previously by Bonnet (1, 2) indicate that this area includes 25,000 acres of good land fit for irrigation, 5,500 acres of salty land that may be reclaimed by washing with fresh water, and 5,000 acres of high salty land that require reclamation with chemicals.

The infiltration rate of the salty area as determined in the field by the method of Nelson & Muckenhirn (4), during the eighth-hour run was slow, i.e. between .03 and .08 inch of water.

This paper reports the results obtained in a field experiment done in that high salty land when sulphur and gypsum were added for reclamation purposes. The yields of two consecutive crops of rice and sugar cane and the specific conductance values of 1:2 soil-water suspensions were used as yardsticks to measure the effect of the chemical used for reclamation.

EXPERIMENTAL

The rice crop—A tract of high salty Aguirre clay was chosen in Lajas valley for the field test. Twenty square plots, each $20' \times 20'$, were placed in three rows; the first and second with eight plots each and the third with four plots. The rows and plots were separated by a ditch 2-feet wide followed by a pathway 5-foot wide and a second ditch. Ditches were placed conveniently to allow for the individual irrigation and drainage of each plot. The plots were grouped into five blocks, and each block was subdivided into four plots for the following randomized treatments:

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[1] Contribution from Soils Department, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, Puerto Rico.

[2] Head Soils Department, Assistant Soil Conservationist, and Assistant Soil Technologist, respectively.

1. Check
2. Leached
3. Sulphur added to the soil at the rate of 218 pounds per acre.
4. Gypsum added to the soil at the rate of 436 pounds per acre.

The sulphur and gypsum were brought to the fields in ground form as milled respectively, by a cement factory and a superphosphate plant in Puerto Rico. The large pieces were smashed on the ground. The chemicals were hoed and mixed well with the surface soil. Each plot was converted into a basin for growing rice under irrigation at a water level of about four inches. This was done by piling surface soil from the adjacent ditches and pathway forming an earth mound around the plot's perimeter (see photo).

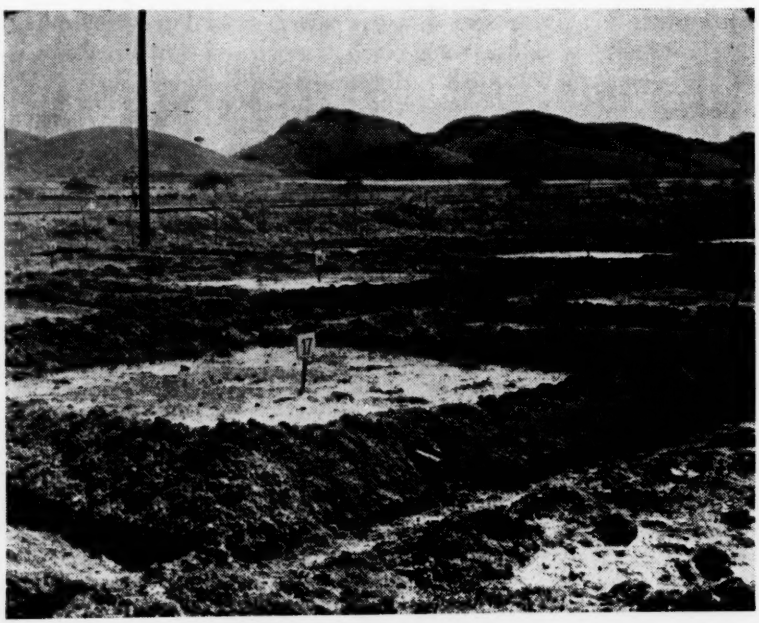

PHOTO OF FIELD TEST IN HIGH SALTY AGUIRRE CLAY IN LAJAS VALLEY

Plots ready for planting rice under continuous irrigation. Inlet water pipe at upper corner of plot. Pipes were removed the second week. Then the basin-type of irrigation was used. Observe ditch, pathway and ditch dividing the plots. Plots 14 and 15 belong to the second row, 17 is the extreme left plot of the four last plots in the third row.

Preliminary washings of soluble salts with irrigation water were given to all treatments except the check. The corresponding plots were flooded early in the morning and kept flooded during working days. The water supply was that from Río Loco, the same irrigation source used successfully for many years in the surrounding good fields of sugar cane.

After the preliminary washings, an inlet and an outlet pipe were placed at convenient heights, in each plot, for the continuous flow of irrigation water for the rice crop.

Ammonium sulphate at the rate of 200 pounds per acre was added to each plot, one day previous to planting. Seeds of rice, Fortuna variety, were broadcast on September 10, 1947 at the rate of four pounds per plot. The germination capacity of the seed was found in the laboratory to be about 70 per cent. The seed was soaked in water the night before planting but was slightly dried out a few hours before planting. Water was run continuously except in non-working hours. After the first week, due to chlorosis in the plants, the system of continuous irrigation flow was abandoned. The plots were then kept wet at all times, by flooding every morning until two weeks before harvest when the water was removed. The crop was harvested on December 10, 1947 at the age of three months.

The sugar cane crop—The same plots and treatments for the rice test were used for sugar cane but with the furrow irrigation system. The corresponding earth mounds were raked into each plot and the surface soil was then leveled. Sulphur and gypsum were applied at the rate of one and two tons per acre, respectively. Four furrows at 5-foot distance were dug in each plot.

The field was planted on January 19, 1948 with cane variety POJ 2878. Three-eyed pieces, one-foot apart, were planted in a row on top of the narrow bank between the furrows. Each plot contained five rows of cane. The field was immediately irrigated by filling the furrows to the top with irrigation water. The water was kept in the furrow by plugging its end with earth. The frequency period of irrigation varied between 8 and 10 days until one-month previous to harvest when no more irrigation water was used.

The crop was fertilized two times: the first, on March 4, 1949 about six weeks after planting; and the second, on May 5, 1949 about nine weeks later. The fertilizer used was only

ammonium nitrate at the rate of 4 pounds per plot in each application or 871 pounds per acre. This corresponds to a total application of 283 pounds of nitrogen (N) per acre based on a guarantee value of 32.5% N in the fertilizer bag.

The crop was harvested on February 1, 1949 at the age of 12½ months. The juice from ten canes selected at random from each plot was expressed out in the Experiment Station's mill. Determinations for sugar content, pH, and specific conductance were run in the cane juices.

After the cane crop was harvested, samples were taken from each plot, of soil layers nine-inch deep down to three-feet, for pH and specific conductance determinations.

OBSERVATIONS AND FIELD DATA

Rice crop—The first week after the rice was planted, an algae-soil crust and the rice seedlings were brought up to the water surface in six plots, including one check, one leached, two sulphur, and two gypsum treatments. Algae growth was also noticeable in the other plots and a general chlorosis sympton developed in the seedlings of the whole field. It was found necessary, as mentioned before, to stop the continuous irrigation flow and proceed with the basin type of irrigation.

The rice plants continued growing fairly well but those in the center of all plots, where the water collected, had a yellowish green color. The rest of the crop was green and more vigorous. The northern half of the plot was better than the southern half. This was due to wind effect blowing from the South.

In two check plots that were not irrigated for three consecutive days, the soil cracked and hardened and the plants began to be affected. They recovered after being irrigated.

A worm attack, possibly *Laphygma frugiperda*, appeared in the fifth week. The worms fed on the leaves and stems of the rice plants. Three sprayings with a solution of 2½ pounds of lead arsenate in 50 gallons of water were succesful in checking the infection.

Some of the rice plants began heading seven weeks after planting. At this time, growth was still poorer in the center of all plots.

The mean yields of the whole plant and the seed rice are given in table 1.

TABLE 1.—MEAN YIELD OF FORTUNA RICE, NINETY DAYS OLD, GROWN IN SALTY AGUIRRE CLAY UNDER IRRIGATION IN LAJAS VALLEY

Number	Treatment	Whole Plant	Seed Rice
		Lbs./A	Lbs./A
1	Check	4,361	996
2	Soil leached previously with water	4,160	953
3	Sulphur added to the soil at the rate of 218 pounds per acre	4,165	898
4	Gypsum added to the soil at the rate of 436 pounds per acre	4,254	828

No significant difference was found between the mean yields of seed rice of the four treatments.

The Sugar Cane Crop—The mean cane yields, in tonnage and sugar per acre for each of the four treatments are given in table 2.

TABLE 2.—MEAN TONNAGE AND SUGAR PER ACRE OF POJ 2878 CANE VARIETY HARVESTED AT THE AGE OF 12½ MONTHS IN SALTY AGUIRRE CLAY AT LAJAS VALLEY

Number	Treatment	Tons Cane per Acre	Tons Sugar per Acre
1	Check	19.28	1.667
2	Soil leached previously with water	14.73	1.196
3	Sulphur added to the soil at the rate of one ton per acre	17.41	1.428
4	Gypsum added to the soil at the rate of two tons per acre	22.68	2.022

No significant difference was found between the means of tons of cane or tons of sugar per acre of the four treatments.

The mean values of specific conductance, soluble salts and pH for the cane juices from each of the four treatments are reported in table 3. The soluble salts were estimated by multiplying the specific conductance by seven.

TABLE 3.—MEAN VALUES OF SPECIFIC CONDUCTANCES, SOLUBLE SALTS AND pH OF SUGAR CANE JUICES OF POJ 2878 CANE HARVESTED AT THE AGE OF 12½ MONTHS IN SALTY AGUIRRE CLAY OF LAJAS VALLEY

Number	Treatment	Specific Conductance*	Estimated Soluble Salts	pH
			p. p. m.	
1	Check	687	4,809	5.72
2	Leached	750	5,250	5.69
3	Sulphur	655	4,585	5.72
4	Gypsum	695	4,865	5.69

* mhos. x 10^{-6} at 25°C.

The mean specific conductances for soil samples taken from each of the four treatments at 9-inch layers down to a depth of 36 inches and their mean pH are given in table 4. The specific conductances were determined in 1-2 soil water suspensions shaken in an agitator for 30 minutes.

TABLE 4. MEAN SPECIFIC CONDUCTANCES AND pH OF SOIL LAYERS TAKEN FROM AGUIRRE SALTY CLAY IN LAJAS VALLEY AFTER THE SUGAR CANE CROP WAS HARVESTED

Soil Depth Inches	Treatment	Specific Conductance*	pH
0–9	Check	186	8.6
0–9	Leached	200	8.7
0–9	Gypsum	188	8.7
0–9	Sulphur	203	8.7
9–18	Check	275	8.6
9–18	Leached	289	8.6
9–18	Gypsum	250	8.6
9–18	Sulphur	294	8.6
18–27	Check	336	8.6
18–27	Leached	372	8.5
18–27	Gypsum	403	8.6
18–27	Sulphur	411	8.6
27–36	Check	445	8.6
27–36	Leached	497	8.5
27–36	Gypsum	452	8.6
27–36	Sulphur	516	8.7

* mhos x 10^{-5} at 25°C. of a 1:2 soil-water suspension.

CHEMICAL ANALYSES OF WATER SUPPLIES

The waters from Río Loco have been used successfully for irrigation in the surrounding sugar cane fields. The chemical analyses of its waters, under normal flow and in flood are reported in table 5. They are also reported for the potential water sources to be used for irrigation of Lajas valley when the project is established.

DISCUSSION

The amount of rice imported (3) in Puerto Rico during fiscal year 1947-1948 was 265,724,074 pounds with a total value of $28,586,575. The production of rice in Puerto Rico for that same fiscal year was 14,800,000 pounds in 25,535 acres with a yield of 580 pounds per acre. That yield is for unfertilized upland rice since in Puerto Rico the growth of paddy rice is limited to a few acres.

The mean yield of all four treatments obtained for a three-month fall crop of paddy rice, Fortuna variety, fertilized at the rate of 200 pounds of ammonium sulphate per acre in salty Agui-

TABLE 5. CHEMICAL ANALYSES* OF WATER SUPPLIES FOR LAJAS VALLEY

Number	River	pH	Specific Cond.**	Total Solids	Parts Per Million								
					Ca.	Mg.	Na.	K.	B.	HCO_3	SO_4	Cl.	NO_3
				p.p.m.									
1	Loco, normal flow	8.7	40	296	16	41	18	10	.028	188	6	17	0
2	Loco in flood	8.5	22	181	11	26	9	0	.026	118	5	11	1
3	Yauco	8.8	28	220	37	9	16	0	.028	136	9	11	2
4	Chiquito	7.7	29	202	36	9	18	8	.130	109	10	11	1
5	Prieto	8.0	29	208	38	8	21	6	.053	117	6	9	3
6	Yahuecas	8.0	23	171	23	9	26	0	.009	94	4	14	1
7	Toro	8.0	22	177	25	9	14	10	.010	104	4	9	2
8	Quebrada Blanca	7.7	11	109	8	7	13	0	.006	17	17	14	3
9	Guayo	7.2	20	175	25	7	13	0	.010	26	14	12	8

* Performed by A. Riera and J. Roldán, Assistant Chemist and Research Assistant in Chemistry, respectively, Soils Department, Agricultural Experiment Station, University of Puerto Rico.

** Specific conductance in Mhos x 10^{-3} at 25°C.

rre clay (table 1) was 919 pounds of seed rice per acre. Deducting 35 percent for the hull's weight, this mean yield corresponds to 597 pounds of rice per acre which corresponds to its yield when grown as upland rice. The chlorotic symptoms of the Fortuna rice variety grown in Lajas valley indicated that it was not suitable as a paddy variety. Research with other suitable rice varieties is needed to know about the potentialities of the highly salty clay lands in Lajas valley for production of paddy rice.

Dr. Jenkin W. Jones, Principal Agronomist in charge Rice Investigations, U. S. D. A. commented as follows: "I do not know of course why Fortuna did not do well under such conditions. Fortuna is grown here under irrigation and is a reasonably productive variety. Of all of our lowland varieties, Fortuna apparently does produce better yields than the others when grown under upland conditions. The proportion of grain to whole plant, in your experiment is quite low, and apparently some factor other than the salinity of the soil might be responsible for the comparatively low yields and similarity in the results from all treatments. Usually, the Fortuna variety requires from 140 to 155 days to mature in Louisiana; hence, the low yields you obtained indicate that conditions in Puerto Rico are very different from those in our Gulf Coast area." The age at maturity of the fall crop of Fortuna rice, harvested in salty Aguirre clay, was 90 days. The mean ratio of whole plant to seed rice, for all treatments, was 4.6 (table 1).

The light applications of sulphur and gypsum of 218 and 436 pounds per acre, respectively, were not effective in increasing significantly (table 1) the yield of the rice crop. The heavier application of one and two tons per acre of sulphur and gypsum, respectively, were not either effective in increasing significantly (table 2) the tonnage and sugar content of POJ 2878 cane.

The cost of sulphur and gypsum for reclamation purposes in Puerto Rico is too high. For the ton of sulphur used (99.5% S) the quotation on February 24, 1947 f.o.b. factory was $42. The cost of the gypsum (78.80% $CaSO_4$) f.o.b. in the field was $38.

The cane juices from all treatments were salty, but were acid in reaction, around pH 5.7 (table 3). The mean specific conductance for the treatments was found to be 697 mhos $\times$ 10^{-5} at 25°C equivalent to an estimated amount of 4879 parts per

million of soluble salts. Juices of 20 canes from non-salty soils gave specific conductances ranging from 130 to 275 mhos $\times$ 10^{-5} at 25°C equivalent to about 910 and 1925 parts per million of soluble salts, respectively. These good juices are slightly less acid, pH 5.8 to 6.0, than the ones from POJ 2878 cane grown in the highly salty land.

All the plots, irrespective to treatments, were alkaline (pH 8.5 to 8.7) in the 3-foot soil profile, after the cane crop was harvested (table 4). The specific conductances of the four 9-inch soil layers were also very high. They increased with depth from a mean of 194 mhos $\times$ 10^{-5} at 25°C in the first 9-inch surface layer to 478 in the 27-36 inch layer. The mean specific conductance for the 3-foot soil layer was 331 mhos $\times$ 10^{-5} at 25°C.

Covariance statistical analyses were made to find whether the salt content of the first 9-inch soil layer, or the salts in the cane juices expressed by specific conductance values, had significant effects on the yields of cane. Results obtained were not significant.

The high magnesium content (41 p.p.m. in normal flow and 26 in flood) of the waters from Río Loco (table 5) which flow through a serpentine region, may have been a cause for masking the effect of the gypsum and the sulphur added to the salty land for reclamation purposes. Low magnesium waters, like those from Río Yauco (9 p.p.m.) and the other sources, are not available now for irrigation in Lajas valley. These good and abundant fresh waters will be the main source for irrigation of the Lajas valley. The high magnesium waters of Río Loco will also be used but provision should be taken to dilute them with the new supplies of fresh waters when the salty lands are to be reclaimed with chemicals.

SUMMARY

There are about 5,000 acres of high salty Aguirre clay in Lajas valley, in southwestern Puerto Rico, that need reclamation to be fit for crop growth. A field experiment was carried there including four treatments: check, leached, sulphur, and gypsum. The leached treatment consisted of preliminary washings with water. The irrigation source was the same used successfully in the good adjacent sugar cane fields for many years. The crops planted were rice and then, sugar cane.

Data reported here include yields of rice in terms of whole plant and seed and of sugar cane in terms of tonnage and sugar content as well as conductivity values of the cane juices. Data are also reported for the pH and the specific conductance values for soil samples taken after the cane was harvested. Chemical analyses of the water supplies are also presented.

No significant results in crop yields due to treatments were obtained. Covariance statistical analyses were made to find whether the salt content of the first 9-inch soil layer, or the salts in the cane juices had significant effects on the yields of cane. Results obtained were not significant.

Reclamation of salty Aguirre clay with sulphur and gypsum was not succesful. It was found that the irrigation water used was high in magnesium salt. These high magnesium waters might be a cause for the negative results.

LITERATURE CITED

1. **Bonnet, J. A.** Laboratory and field studies in an alkaline earth solonchak area of Puerto Rico to be irrigated. Soil Sc. Soc. of America. Proc. 1946 (11): 480–483.

2. **Bonnet, J. A.** Soil Studies in Lajas valley (Jul. 1945–Aug. 1947). Bul. 86 Univ. P. R., Agric. Expt. Sta. 68 p., Aug. 1950.

3. **Department of Agriculture and Commerce.** Bureau of Commerce, Annual Book on Statistics of Puerto Rico. Fiscal year 1947–48. Table 127, p. 276, tables 157, 158, 159, p. 291.

4. **Nelson, L. B.** and **Muckenhirn, R. J.** Field percolation rates of four Wisconsin soils having different drainage characteristics. J. Am. Soc. Agron. 33 (11): 1028–1036, 1941.

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